Indicator: Land Cover Change in the Puget Sound Basin (250R)

Changes in land use and land cover can alter the basic functioning and resilience of local ecosystems, such as small watersheds, and larger ecosystems, such as the drainage basin of Puget Sound. Ecoregions denote areas of general similarity in ecosystems and in the type, quality and quantity of environmental resources (Omernik, 1987). The Puget Sound river valley low-lands, Cascade Mountain range, and Olympic Mountain range are examples of notable ecoregions in northwestern Washington. At more local scales, changes in land use and land cover can alter the basic physical, chemical, and biological processes associated with watersheds (NWP, 1995; Thom and Borde, 1998). While local impacts to a landscape may appear to be insignificant, their combined impacts on watersheds can have substantial effects on water quality, species composition, and flood buffering (PSAT, 2002; 2004). Such impacts are often referred to as 'cumulative effects.' Forest and urban land cover are two of the most important factors affecting the condition of watersheds in the Puget Sound Basin over a wide range of spatial scales (Alberti and Marzluff, 2004; Alberti, 2005).

This indicator compares changes in three metrics between 1995 and 2000 for the U.S. portion of the basin and between 1992-1999 for the Canadian side of the basin. It represents the change in the sum of all patches of urban, forested, or agricultural patches divided by total landscape area in the given watersheds. The underlying data are derived from four assembled USGS Landsat scenes covering the US portion of the Puget Sound Basin and from a combined scene covering the Canadian land area. The land cover data for all USGS 6th field watersheds in the basin was produced from NOAA C-CAP data and from Canadian BTM data. The USGS Hydrolgic Units (HUCs) and Canadian watershed groupings provide topographically delineated watersheds which are aggregated, or rather 'nested', into larger sub-basin and basin units.

What the Data Show

Little or no change in forest cover was observed in 2,068 watersheds in the Puget Sound and Georgia Basin between 1995 and 2000 for the U.S. side of the basin and between 1992 and 1999 for the Canadian side of the basin (Figure 250R-1). However, 279 watersheds saw at least 2.5% of their total area converted from forest cover to some other classification. More concentrated and rapid forest conversion occurred in coastal and mid-elevation watersheds, where there are more extensive private forest lands. At somewhat higher elevations, however, another group of 205 of watersheds showed a net increase in forest cover, as young stands have re-grown into more mature forest cover classes. The watersheds gaining forest cover were mostly in areas containing higher proportions of forest land under public ownership, occurring mostly at the higher elevations along the slopes of the Cascade Mountains and Olympic Mountains. A similar pattern is observed for the northern, British Columbia side of the basin, where the higher elevation watersheds along the eastern portion of the basin generally gained mature forest cover while the coastal watersheds along the south-eastern side of Vancouver Island showed more concentrated loss of forest cover.

While little or no change in urban land cover occurred in 2,329 watersheds of the basin, there was an increase in urbanization across many low elevation watersheds and shoreline areas, with 158 watersheds gaining urban area between 0.7% to 2% of the total area of their watershed within the indicator timeframe and another 58 watersheds showing increases between 2% and 19%. Unlike the Canadian side of the basin, which shows more concentrated patterns of urbanization, urbanization is more widely distributed across watersheds in the U.S. side of the Basin. Once watersheds have developed roughly 10% of their drainage area into an impervious or paved condition, there is a high potential for physical, chemical, and biological impairments to both water quality conditions and other aquatic resources (NWP, 1995; McMurray and Bailey eds., 1998). Current assessments are finding that relatively large numbers of Puget Sound watersheds are nearing or exceeding this level of development (Alberti et al., in preparation).

Agricultural lands showed little change in 2,632 watersheds in the basin, but 26 watersheds indicated a loss of agricultural land of as much as 1% of the watershed area within the indicator timeframe. The loss of agricultural land in these watersheds was mostly due to a conversion to urban land cover. In the same period, 67 watersheds gained agricultural land, of which 65 were in British Columbia and were associated with the inclusion of a mixed residential and small-scale agricultural category. This increase in agricultural and urban land cover generally results from conversion of forest land. In the U.S. portion of the basin, forest land appears to be converted more directly from forest to urban cover without any increase in agricultural land.

Indicator Limitations

- While the U.S. C-CAP data and the Canadian BTM data have similar and overlapping time periods, as currently presented, the U.S. data reflect change between 1995 and 2000 and the Canadian data reflect change between 1992 and 1999. The data are currently being normalized to an annual rate of change.

- The size of the data pixels and the minimum mapping unit size affects the classification of certain features such as narrow riparian corridors, and can affect the percentges in the indicators.

Data Sources

1995-2000 C-CAP trend assessment: Chris Davis or Matt Stevenson w/ CommEnSpace. http://www.commenspace.org (206)749-0112
2002 Landsat status assessment: Marina Alberti, Urban Ecology Research Lab, Department of Urban Planning, University of Washington. malberti@u.washington.edu (206) 685-9597

Links for this indicator and the supporting data layers will be available through the Region 10 website later this spring. Please contact Michael Rylko. Rylko.michael@epa.gov.

References

Alberti, M. 2005. The Effects of Urban Patterns on Ecosystem Function. *International Regional Science Review*. Forthcoming.

Alberti, M. and J. Marzluff. 2004. Resilience in Urban Ecosystems: Linking Urban Patterns to Human and Ecological Functions. Urban Ecosystems 7:241-265.

Alberti, M. et al. 2004. Urban Land-Cover Change Analysis in Central Puget Sound. Photogrammatic Engineering & Remote Sensing Vol. 70, No. 9 pp. 1043-1052.

Northwest Environment Watch (NWEW). 2002. This Place on Earth: Measuring What Matters. Seattle WA

Northwest Environment Watch (NWEW. 2004. Cascadia Scorecard: Seven Key Trends Shaping the Northwest. Seattle WA

Northwest Forest Plan (NWP). 1995. Ecosystem Analysis at the Watershed Scale, Federal Guide for Watershed Analysis. USFS Regional Ecosystem Office, Portland, OR.

Omernik, J.M. 1987. Level III and IV Ecoregions for the Continental US, Annals of the Association of American Geographers, v. 77, no. 1, pp. 118-125.

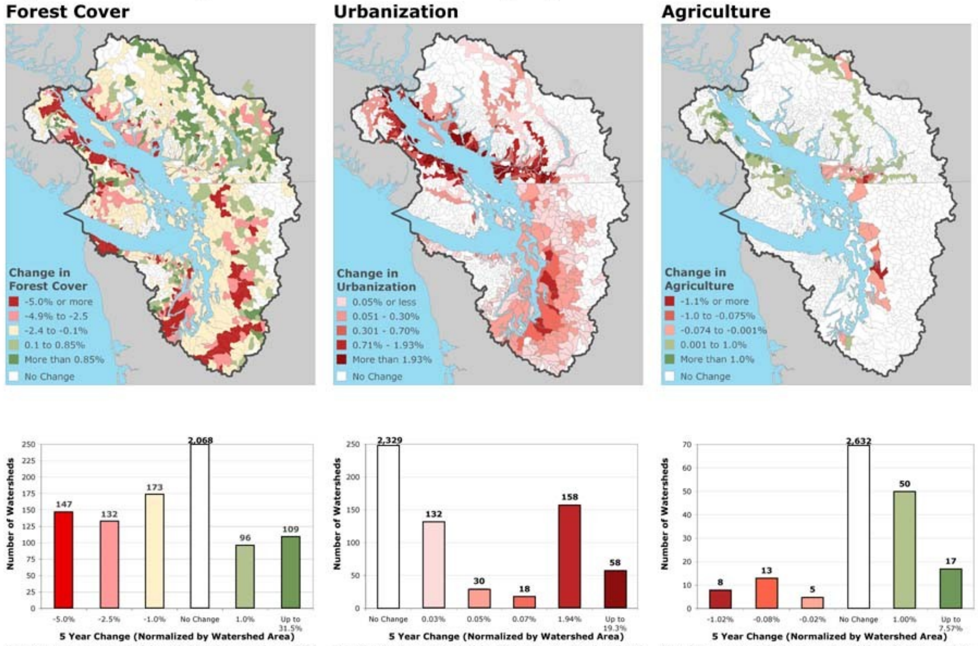
Puget Sound Action Team. 2002. Puget Sound Update. Eighth Report of the Puget Sound Ambient Monitoring Program. Olympia, WA

Puget Sound Action Team. 2004. State of the Sound. Report to the Washington State Legislature. Olympia, WA

Puget Sound Georgia Basin (PSGB) Transboundary Indicator Indicator Working Group. 2002. Georgia Basin-Puget Sound Ecosystem Indicators Report. Washington State Department Of Ecology Publication Number 02-01-002.

Graphics

Figure 250-1: Puget Sound Land Cover Change by Watershed



Forest cover is comprised of three C-CAP classes and two BTM classes. The C-CAP classes are Coniferous Forest, Deciduous Forest, and Mixed Forest. The BTM classes are Young Forest and Old Forest. For the C-CAP data, total forest area for 1995 was subtracted from total forest area for 2000, and BTM data is a single data source containing change classes for 1992 - 1999. For both data sets the result is expressed as the percentage of the total area of each watershed. Across the entire basin, little or no change occurred in 2,068 watersheds, 279 watersheds lost 2.5% or more forest cover, and 205 watersheds gained forest cover over the respective change periods.

Urbanization is comprised of the High Intensity Developed and Low Intensity Developed C-CAP classes and a single Urban BTM class. Little or no change occurred in 2,329 watersheds, 48 watersheds saw an increase in urbanization between 0.05% and 0.70%, and 216 watersheds gained urbanization equivalent to as much as 19.3% of their total area (Bowen Island, in British Columbia's Howe Sound).

Very few watersheds in the Puget Sound/Georgia Basin contain land cover classified as Cultivated in the C-CAP or BTM data. The BTM data contains a Agriculture class and a secondary class called Residential Agriculture Mixtures, which has no equivalent in the C-CAP data. No change in the extent of agricultural land occurred in 2,632 watersheds, 26 watersheds lost agricultural land, and 67 watersheds gained agricultural land. Sixty-five of the watersheds that gained agriculture are located in British Columbia, and the gain is due largely to the inclusion of the mixed agriculture/residential class.

March 16, 2005
Cartography by
CommEn Space
www.commenspace.org

R.O.E. Indicator QA/QC

Data Set Name: LAND COVER CHANGE IN THE PUGET SOUND BASIN
Indicator Number: 250R (114764)
Data Set Source: CCAP and Landsat Satellite Data
Data Collection Date: CCAP 1995 and 2000; Landsat 2002.
Data Collection Frequency: irregular
Data Set Description: Urbanization of Puget Sound Watersheds
Primary ROE Question: What are the trends in the extent and distribution of the Nation's ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The proposed landscape indicator metrics have been shown to represent important conditions and stressors to the physical integrity of both terrestrial and aquatic ecosystems, including watersheds at a range of spatial scales. The proposed metrics are valuable indicators for assessing the condition of local ecosystems and corresponding resources including water quality, flow, habitats, and utilization of water and fisheries resources. The proposed metrics are also responsive to time series analysis. Alberti, M. and J. Marzluff. 2004. Resilience in Urban Ecosystems: Linking Urban Patterns to Human and Ecological Functions. Urban Ecosystems 7:241-265.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. A limited time series for all of the watersheds within the basin has been produced from NOAA C-CAP remotely sensed data and analyzed by USGS 5th field watershed units. This trend analysis will only use a general and commonly used land cover classification that includes 4 major cover clasess (i.e. urban, forest, agriculture, and bare ground). When normalized as a percent of similarly classed lands within the respective watershed units, this will provide a reasonable basis for generalized trends in land-cover change for the period from 1995 to 2000. The Land Cover Status for the Puget Sound Basin for 2002 is comprised of four assembled USGS Landsat scenes covering the US portion of the Puget Sound Basin. This assembled coverage has been classified using a more discriminating methodology that enables assessment of both composition and configuration metrics and yet is still compatible with more generalized, hierarchical land cover classification schemes (including those used in the 1995-2000 C-CAP general trends in land cover assessment). This makes it quite useful and well suited for more refined trend monitoring of land cover changes. Watershed Analysis Units (WAUs) and USGS Hydrolgic Unit Codes (HUCs) are both topographically delineated watersheds, useful for studying environmental concerns. Reference: Alberti, M., Weeks, R., and S. Coe. 2004. Urban Land Cover Change Analysis for the Central Puget Sound: 1991-1999. Journal of Photogrammetry and Remote Sensing 70:1043-1052.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Changes in land use and land cover can alter the basic physical, chemical, and biological processes associated with ecosystems (NWP, 1995; Thom and Borde, 1998; Alberti and Marzluff, 2004). Metrics that serve as indicators of landscape patterns aim to measure two major characteristics of the landscape: land cover composition and spatial configuration. Landscape composition refers to the presence and amount of different patch types within the landscape without explicitly describing its relative spatial features. The composition metrics proposed include percent land cover by each land cover class - reflecting what percentage of the study area is covered by a given land cover type. Percentage of landscape cover quantifies the proportional abundance of each land cover type in the defined landscape. It is a measure of landscape composition which is important in many ecological applications. The two compostion metrics being reported are: Percent of Urban Land Cover is the percent of paved land and is calculated by the sum of the area of all paved patches divided by total landscape area. Percent of Forest Cover is the percent of forest land cover and is calculated by the sum of all patches of forested patches divided by total landscape area. Alberti, M. and J. Marzluff. 2004. Resilience in Urban Ecosystems: Linking Urban Patterns to Human and Ecological Functions. Urban Ecosystems 7:241-265. Northwest Environment Watch (NWEW). 2002. This Place on Earth: Measuring What Matters. Seattle WA Northwest Environment Watch (NWEW. 2004. Cascadia Scorecard: Seven Key Trends Shaping the Northwest. Seattle WA Northwest Forest Plan (NWP). 1995. Ecosystem Analysis at the Watershed Scale, Federal Guide for Watershed Analysis. USFS Regional Ecosystem Office, Portland, OR.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

There is a high level of correlation of the proposed indicator metrics to both the primary ROE question (trends in land use)and secondary ROE question (water quality stressors and conditions). Landsat and C-CAP data are collected on an ongoing basis, however, the utility of any particular scene is dependent on both duiurnal and seasonal variables (i.e. vegetation condition, whether conditrions, light conditions, etc...).

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems?

The Puget Sound lowland ecoregion represents an ecosystem that is under significant stress with many habitats and species considered at-risk of local extirpations. Land development that results in significant changes to land cover has been shown to have extensive effects on watershed processes that maintain water quality, aquatic habitat, etc. Reference: Puget Sound Georgia Basin (PSGB) Transboundary Indicator Indicator Working Group. 2002. Georgia Basin-Puget Sound Ecosystem Indicators Report. Washington State Department Of Ecology Publication Number 02-01-002.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

In general terms, yes. Research has shown that once watersheds begin approaching or exceeding about 10% of their drainage area in an impervious or paved condition, there is a high potential for physical, chemical, and biological impairments to both water quality conditions and other aquatic resources. Realted research has shown that watersheds, particularly those along the west side ranges of the Pacific Northwest, require about 65% forest cover to retain the hydrological processes that minimize surface water runoff during storms and retain and infiltrate water into ground-water and summer base flows in local streams and rivers. References: G. McMurray and R. Bailey (eds.). 1998. Change in Pacific Northwest Coastal Ecosystems. NOAA, Coastal Ocean Office, WA D.C. T. Schueler and H. Holland (eds.) 2000. The Practice of Watershed Protection. Center for Watershed Protection, WA D.C.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Primary reference: Alberti, M. R. Weeks, and S. Coe. 2004. Urban Land-Cover Change Analysis in Central Puget Sound. Photogrammatic Engineering & Remote Sensing Vol. 70, No. 9 pp. 1043-1052. also see other publications and methodologies via: http://www.urbaneco.washington.edu/

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

At this point in time, the complete digital data sets are not available for general access. Data summaries (classified images), metadata, and analytical methodologies are currently available. The unclassified sattelite scenes are generally available. For 1995-2000 C-CAP trend assessment: Chris Davis or Matt Stevenson w/ CommEnSpace. http://www.commenspace.org (206)749-0112 For 2002 Landsat status assessment: Marina Alberti, Urban Ecology Research Lab, Department of Urban Planning, University of Washington. malberti@u.washington.edu (206) 685-9597

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. See, Alberti, M. R. Weeks, and S. Coe. 2004. Urban Land-Cover Change Analysis in Central Puget Sound. Photogrammatic Engineering & Remote Sensing Vol. 70, No. 9 pp. 1043-1052. also see other publications and methodologies via: http://www.urbaneco.washington.edu/

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The principle and co-investigators for this research and resulting methods have many related publications in this field which are broadly available. Primary reference: Alberti, M. R. Weeks, and S. Coe. 2004. Urban Land-Cover Change Analysis in Central Puget Sound. Photogrammatic Engineering & Remote Sensing Vol. 70, No. 9 pp. 1043-1052. also see other publications and methodologies via: http://www.urbaneco.washington.edu/

T4Q1 Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

N/A

T4Q2 Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes, an accuracy assessment is available in: Alberti, M. R. Weeks, and S. Coe. 2004. Urban Land-Cover Change Analysis in Central Puget Sound. Photogrammatic Engineering & Remote Sensing Vol. 70, No. 9 pp. 1043-1052. also see other publications and methodologies via: http://www.urbaneco.washington.edu/

T4Q3 Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

No. The analysis is run for a very large number of sampled pixels. While error for a given pixel is certainly possible, the large number of pixels sampled and strong observed patterns provide a high level of credibility to the indicator.

T4Q4 Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

There are other metrics that provide useful indictors of landscape change. There are also other scales of analysis and assessment of these and other relevant metrics. The metrics presented have been selected for clarity and ease of presentation. Both the size of the data pixels and the minimum mapping unit affects the classification of certain features such as narrow riparian corridors.